Multi-Perspective Multi-Layer Interaction on Mobile Device

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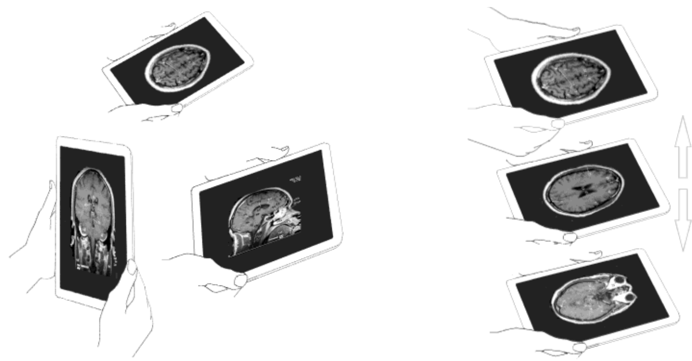

Figure 1: The figures on the left show the orientation-aware interaction while the figures on the right illustrate the depth-aware interaction in horizontal plane.

ABSTRACT
We propose a novel multi-perspective multi-layer interaction using a mobile device, which provides an immersive experience of 3D navigation through an object. The mobile device serves as a window, through which the user can observe the object in detail from various perspectives by orienting the device differently. Various layers of the object can also be shown while users move the device away and toward themselves. Our approach is real-time, completely mobile (running on Android) and does not depend on external sensor/displays (e.g., camera and projector).

ACM Classification: H.5.2. [Information interfaces and presentation]: User Interfaces – Interaction styles; Input devices and strategies

Keywords: Multi-Perspective; Multi-Layer Interaction; Spatially Aware Displays; Optical Flow; Mobile

INTRODUCTION
Visualizing and manipulating information beyond a flat surface can provide a more vivid experience. metaDESK [1] explored how physical objects can be merged with 2D digital world. Izadi et al. [2] introduced SecondLight, a type of interactive surface technology based on a switchable projection screen, which can show different contents on a tabletop with an extra piece of display above it. Peephole Displays [3] followed a metaphor of viewing the world through a small hole. By tracking the pen movement of the PDA, different partial views of the entire target are shown accordingly on the display. But Peephole Displays does not consider the orientation and depth of the observed object. Paper-lens related papers [4]–[6] presented a spatially-aware handheld lens that can augment content beyond a tabletop surface. They also investigated the interaction property of the depth beyond the tabletop. Hinckley et al. [7] specifically developed an interface for 3D neurosurgical visualization. The interface was designed as if a cross-sectioning plate cuts through a miniature head.

Comparing with these works, our approach benefits from the following points: 1) it does not depend on a digital tabletop; 2) it depends only on the sensor/displays of the mobile device rather than external sensor/displays (e.g., camera, projector) 3) it is aware of 3D orientation; the user can observe 3D orthogonal perspectives of an object; 4) it is depth-aware from different perspectives; the device can be moved away and toward the user to show different layers of information in real-time; and 5) it is completely portable.

Our approach has both orientation and depth awareness using the camera and inertial sensors (i.e., magnetic sensor, gyroscope and, accelerometer). By fusing the accelerometer and magnetic sensor's data, we can figure out the mobile device's orientation, i.e., whether it is in horizontal or vertical plane. If the device is in vertical plane, the gyroscope data is used to infer the rotation. To sense the depth in a specific perspective, we analyze the optical flow on the images captured by the device's rear camera.

METHODOLOGY
Mobile device can be imagined as a blade. Its display shows the image sliced from a particular orientation in a certain depth. In our current prototype, we implement mul-

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ti-layer view from three orthogonal perspectives along the x, y, and z axes. Observing various layers and perspectives requires: (i) changing the mobile device's orientation; and (ii) moving the mobile device along that perspective.

First we use the accelerometer and magnetic sensor's data to get the device's approximate orientation; whether the device is in horizontal or vertical plane. Second, if the device is in vertical plane, we use the gyroscope's data to determine the device's orientation in that plane (e.g., if the gyroscope detects a 90 degree rotation, the display shows the view from left to right). Arbitrarily oriented slices can be generated by morphing the images taken from up to three orthogonal perspectives.

To recognize the mobile device's back and forth movement, we use the device's rear camera instead of its accelerometer. From the user experience view point, the user normally moves the device stably back and forth while observing different layers and exploring the content. Accelerometers are good at fast unstable and tilt motion recognition whereas cameras are able to well receive gentle stable motion. While capturing images from the device's rear camera, we (i) downsample images (to make the following operations computationally efficient for the mobile device), (ii) convert the images to grayscale, and (iii) extract corner points with big eigen values in the image. Sparse iterative version of Lucas-Kanade optical flow in pyramids tracking [8] is used to track corner points in the adjacent images. Based on our previous work [9], moving back and forth gestures are recognized by analyzing the movement patterns of such corners (Fig. 2). As the user moves the device away, the distance between the rear camera and the tracked corner points in the real world decreases. In Fig. 2, the corners move towards the outskirt (i.e., away from their center). So the average distance between corner points and their center increases. The relative change in the distance indicates whether the user moves the device away/toward him/herself (i.e., the device's depth relative to the user). We calculate the ratio of the current distance over the previous one. If the ratio exceeds a threshold (1.03), the user is moving the device away; otherwise, if the ratio is smaller than a threshold (0.97), the user is moving the device toward him/herself. To reduce the hand jitter effect, we apply a medium filter (with window size 3) to the ratio. Several optimizations have been performed to make computation efficient on the mobile device including downsampling the raw images to small size of 320×240 and converting them into grayscale.

To visualize all depth layers' information, we added a calibration phase in which the user holds the device and moves it to the farthest/nearest comfortable points. The relative ratio change is recorded to show the first and last layers at the two ends.

CONCLUSION

In this paper, we proposed a novel orientation and depth-aware multi-perspective and multi-layer interaction on mobile device. It makes use of available sensors on mobile

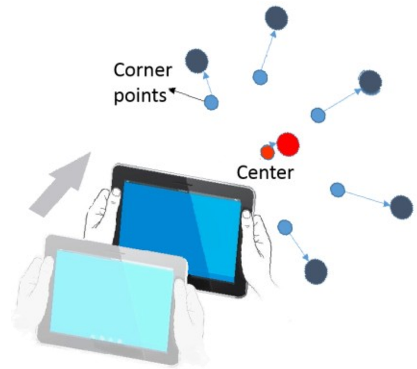

Figure 2: Depth-aware method: while moving the mobile device away from the user, the distance between the rear camera and corner points in the physical world decreases. The corners' positions in the images move towards outskirt (i.e., away from their center).

device such as camera, accelerometer, gyroscope and magnetic sensor. The proposed approach provides 3D navigation of content in details from various depth and perspectives. This can help user locate certain features while exploring the content in real time (e.g., locating tumor by navigating through MRI images). As future work, we will improve the visualization of images from arbitrary orientation and depth by doing sophisticated morphing and rendering. We also plan to incorporate temporally changing models such as fMRI images to explore different temporal states of a layer; for example one would be able to observe the mental state of happiness in a series of fMRI images.

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